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TECHNIQUES OF SHIPBUILDING AND RATES OF PRODUCTION APPARENT IN SOVIET SERIAL CONSTRUCTION OF KAZBEK-CLASS TANKERS AND AKTYUBINSK-CLASS REFRIGERATOR VESSELS

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TECHNIQUES OF SHIPBUILDING AND RATES OF PRODUCTION APPARENT IN SOVIET SERIAL CONSTRUCTION OF "KAZBEK"-CLASS TANKERS AND "AKTYUBINSK"-CLASS REFRIGERATOR VESSELS*

I. Introduction

In the postwar years the USSR has developed standardization in shipbuilding to a higher degree than have most Western shipbuilders. Sectional construction and assembly line methods have been used where vessels are constructed in large numbers.

Soviet shipbuilders in 1952 began serial construction of the Kazbek-class tankers in 3 shipyards and in 1955 began serial construction of the Aktyubinsk-class refrigerator vessels in 1 shipyard. More than 50 tankers and 12 refrigerator vessels have been completed.

Soviet press and technical journals have given much publicity to reduction in cost and in construction time achieved by serial construction and improved methods in prefabrication and assembly. This report examines the principal construction techniques and apparent construction time for vessels, both on the shipbuilding ways** and in fitting-out, of the two classes of vessels in an attempt to evaluate Soviet practice.

II. Program for "Kazbek"-Class Tankers

The basic characteristics of the Kazbek-class tanker are as follows: length over-all, 477 feet; length between perpendiculars, 453 feet; breadth over-all, 63 feet; loaded draft, 28 feet; full load displacement, 16,250 metric tons; and light ship weight, 4,820 metric tons. The vessel's propulsion plant consists of two 2,000-horsepower diesel engines driving one screw through hydraulic couplings and reduction gears.

An examination of construction of this class in each of the three shipyards follows.

A. Kherson Shipyard No. 102 in Kherson.

Kherson Shipyard No. 102 in Kherson is a new shipyard. Construction of this shipyard was started in the late 1940's, and the shipyard was activated in the last half of 1952. It probably has the most modern equipment of any shipyard in the USSR. The shipyard has two shipbuilding ways. Each way is level and is about 1,700 feet long. The first part of each way, about 700 feet long, is covered with an open (not roofed) steel structure which supports four 50-ton bridge cranes over the way. The main hull assembly takes place under this structure. The remaining part of each way, about 1,000 feet long, has no crane-supporting superstructure. This part is used for fitting out vessels, and each way is served by two 15-ton mobile tower cranes. Each shipbuilding way consists of 3 sets of rails on which are positioned about 32 trucks per vessel--that is for Kazbek-class tankers. The trucks are interconnected by adjustable steel rods. On the trucks are mounted the cradles which support the vessel during the whole assembly and fitting-out period. The three sets of rails are extended from the construction area into the launching basin through which completed vessels are lowered into the Dnepr River.

The construction part of each shipbuilding way is divided into three construction positions.

* For the period from 1951 to the last half of 1958.
** The terms shipbuilding way and way, as used in this report refer to the facility on which a ship is finally assembled.

In position I the stern "block section" with the propulsion plant and propeller shafting are assembled. This stern section is approximately one-third of the length of the tanker. Also installed at this position are the auxiliary boiler, engine room auxiliaries, and the superstructure sections which were assembled in the preassembly areas. Upon completion of this phase the vessel is moved (on the trucks) to position II, where the mid-ship and bow sections are erected from flat sections also assembled in the preassembly areas. Also installed are some of the midship super-structrres. Other components installed at this station are the pump-room machinery, rudder, steering engine, and capstan. The vessel then is moved to position III, where the stack, masts, booms, winches and cargo-handling gear, cat-walks, pump-room operating stand, anchors, and anchor windlass are installed. Following the completion of work at position III the vessel is moved into a launching basin. This basin, surrounded by an earth embankment having 3 water-tight gates, has 2 levels--1 which is level with the rails of the shipbuilding way and 1 which is sufficiently below the water level of the Dnepr River to permit movement of vessels from the launching basin to the river. The launching procedure consists of flooding the basin, reported to require 12 to 18 hours, until the vessel is afloat. The vessel then is moved to the deeper section of the basin, where it remains until that part of the basin above the water level of the Dnepr is drained. As the vessel now is floating at the level of the river, it is moved through a water-tight gate to the outfitting quay where certain machinery tests are conducted and provisioning of the ship takes place.

The following table shows the amount of work (presumably in percentage of total direct man-hours) performed in the shops (steel fabrication and preassembly), at each of the 3 positions, and at postlaunching outfitting and trials.

Table Showing Work Progress

for a Tanker in the Various Stages of Construction

Percentage

	Progress Percentage					
		Positions				
Designation of Work Shop	Shops and Preassembly	I	II	III	Post-launching Outfitting	Tests and Trials
Hull fabrication	7.00					
Hull subassembly	18.00					
Assembly on shipbuilding ways	2.90	4.70	11.40			
Pipe work	0.90	1.10	3.40	1.60		
Installation and tests of machinery		0.92	3.40	5.90	3.10	2.40
Mechanical work	3.00					
Woodwork and painting	3.45	0.82	2.75	3.50	2.70	
Fitting out	5.85	0.54	4.40	3.30	0.90	
Rigging	0.30	0.32	0.60	0.60	0.25	
Total	41.40	8.40	25.95	14.90	6.95	2.40

The Kherson Shipyard between the latter part of 1952 and the first half of 1958 constructed 21 tankers. Figures 1 and 2* show the estimated time to construct each tanker, based on an analysis of reported deliveries and construction techniques used by the shipyard. The average construction time for each tanker (keel-laying to delivery) was about 16 months. Construction rates up to mid-1955 appear to be about 18 months per vessel. Thereafter, the construction time decreased to about 14 months per vessel with the vessel, Moscow Festival being delivered in 12 months. The Soviet press gave much publicity to the delivery of this vessel 2 months ahead of schedule.

Figure 3* shows the time between launchings for each shipbuilding way and indicates an average of about 5-1/3 months. The first 10 vessels averaged about 6 months between launchings and the last 11 about 4-1/2 months. The shortest time of 3 months in the spring of 1957 resulted from an accelerated effort to launch the Moscow Festival ahead of schedule.

On the basis of a construction time of 12 months (the same as for the Moscow Festival) construction per month per way is estimated at slightly more than 1,000 metric tons per shipbuilding way.** The average construction for all tankers was about 750 tons per month per way.

In conclusion, it appeared that construction time had been reduced about 22 percent during the 5-year period. Because this shipyard was a new one which employed new construction techniques and because the tanker program was the first program undertaken in the shipyard, a large portion of the reduction in construction time is attributable to the normal breaking-in period of the shipyard.

B. Admiralty Shipyard No. 194 in Leningrad.

Admiralty Shipyard No. 194 in Leningrad is an old-line shipyard with considerable experience in constructing both naval and merchant vessels. The shipyard has 2 principal shipbuilding ways, each about 700 feet long. These ways are inclined. Both the shipbuilding ways and the fitting-out berth are served by mobile tower cranes. The north way is served by 4 mobile tower cranes and the south way by 5 mobile tower cranes.

An article appearing in Sudostroyeniye (Shipbuilding), No. 8, Leningrad, August 1957*** states, "The production procedures adopted made it possible to complete in the plant's shop about 52 percent of the total volume of work to build the tanker, including fabrication of superstructure blocks. The volume of building ways work amounts to about 34 percent of the total volume." See p. 9 , Appendix A, for a tabulation showing a percentage distribution (presumably in percentages of total direct man-hours) of work in the shops, on the ways, and after launching (fitting-out) and trials and tests. It is estimated that the vessel is about 65 percent complete at launching; the remaining 35 percent of work is done after launching at the fitting-out quay and at tests and trials.

This shipyard constructed 7 tankers on the south way and 11 tankers on the north way. Figure 4* shows the estimated schedule of construction for both ways. Figure 5* shows the estimated construction time for each vessel and the time between launchings for the north way only.

* Following p. 3 .

** Assuming a light ship weight of 4,820 metric tons and 85 percent of the weight in place at the time of moving from position II to position III.

*** See Appendix A.

The average construction time (from keel laying to delivery) for all tankers constructed in the shipyard was 15 months.

Construction of tankers began in this shipyard in 1952, and until 1955 only one tanker at a time was constructed on each shipbuilding way. In early 1955 a program was initiated at this shipyard to make greater utilization of way space. Under this program the stern section, similar to that constructed in the first position at Kherson, was constructed at the head of the way while another tanker was under construction at the foot of the way. After the launching of the tanker at the foot of the way the stern section was moved to the foot of the way, and while this tanker was being completed, a new stern section was started at the head of the way. This practice increased slightly the overall construction time for each tanker, but it considerably increased the tonnage constructed per way per year. Figure 5* shows that for the earlier construction about 6-1/4 months were required between launchings, whereas for the later vessels, with the exception of the last 2 vessels which were modified slightly for sale to East Germany, the time between launchings was reduced to about 4-1/2 months. The tanker Vladimir was launched in 3 months and 8 days following the launching of the Kursk from the same way. It should be noted that although the Sudostroyeniye article (See Appendix A page 9) states that "transfer to this method (pyramidal scheme) was one of the important factors which made it possible to reduce the work time on the building ways from 8 months on the first ship assembled by the compartment method to 3 months and 8 days on the tanker Vladimir," the time actually refers to time between the launching of the Kursk and the Vladimir and does not accurately reflect the total construction time on the shipbuilding way of an estimated 7 to 8 months (See Figure 4.*) This practice amounted to about an increase of 25 percent in tonnage constructed per way per year.

On the basis of a launching every 4 months construction per month per shipbuilding way is estimated at slightly more than 1,000 metric tons. Average construction for all tankers, except the 2 tankers for East Germany, was about 720 metric tons per month per way.

The increase in time on the shipbuilding way, occasioned by the practice of constructing one and a fraction tankers simultaneously, is probably attributable principally to an increased demand on crane facilities and partly to the lack of a proportionally expanded labor force.

C. Nosenko Shipyard No. 444 in Nikolayev.

Nosenko Shipyard No. 444 in Nikolayev, although completely destroyed during World War II and rebuilt in the immediate postwar years, is an old-line shipyard with considerable experience in constructing both naval and merchant vessels. The facilities and shipyard practice used in constructing vessels of the Kazbek-class are similar to those in the Admiralty Shipyard in Leningrad.

Little information is available about construction of merchant vessels in this shipyard other than that given in the Soviet press. A study of construction of cruisers, tankers, whale catchers, fish factory ships, and Ges-class cargo vessels seems to indicate that all the tankers were constructed on one way (second way, new cruiser way, from the eastern side of the shipyard).

Figure 6** shows an estimated schedule of construction. This shipyard produced 13 tankers. Because the Kazbek (after which vessel Soviet shipbuilders named this class), however, was the prototype vessel, it was not included in construction estimates for the Nosenko Shipyard. It would appear that the Volga-Don was the first series-constructed vessel of the class.

* Following p. 3, above.
** Following p. 4.

Figure 1

USSR: ESTIMATED CONSTRUCTION SCHEDULE
KAZBEK-CLASS TANKERS
KHERSON SHIPYARD No. 102, KHERSON

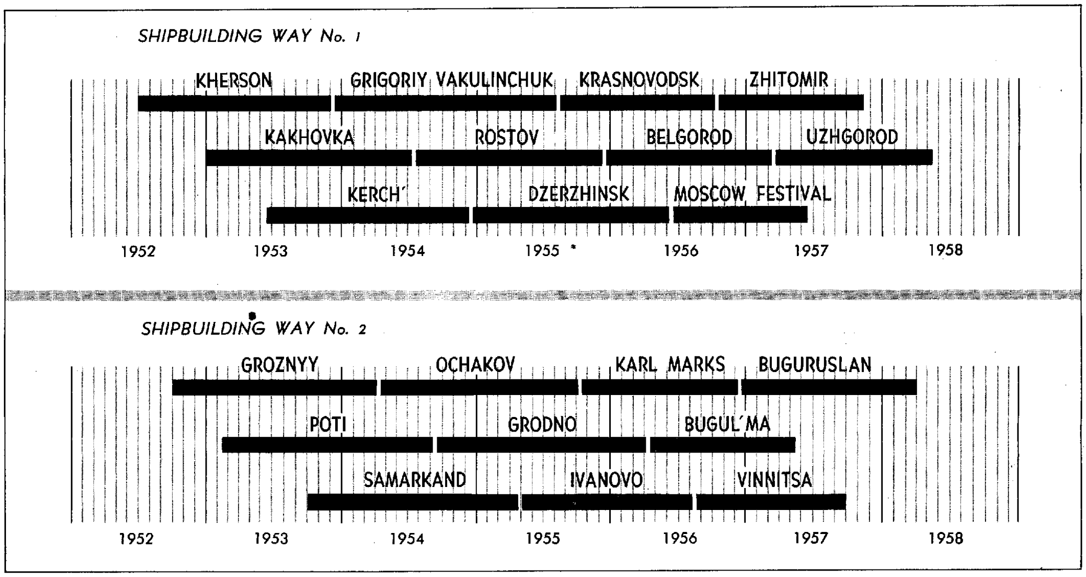

Figure 2

CONSTRUCTION TIME, IN MONTHS
KAZBEK-CLASS TANKERS
KHERSON SHIPYARD No. 102

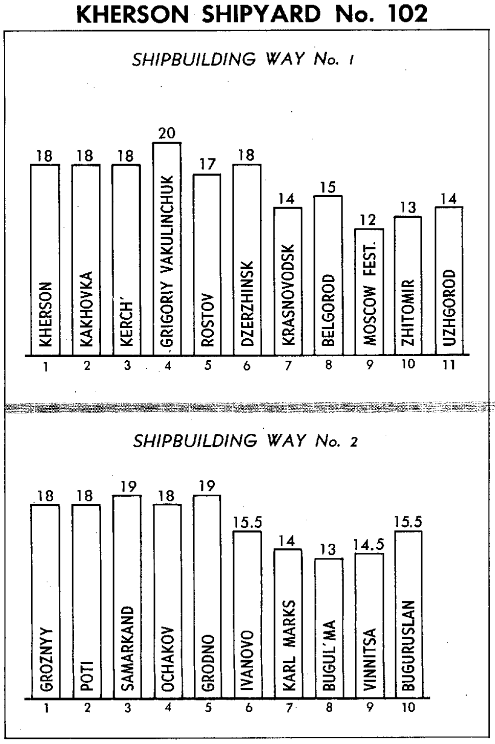

Figure 3

TIME BETWEEN LAUNCHINGS
KAZBEK-CLASS TANKERS
KHERSON SHIPYARD No. 102

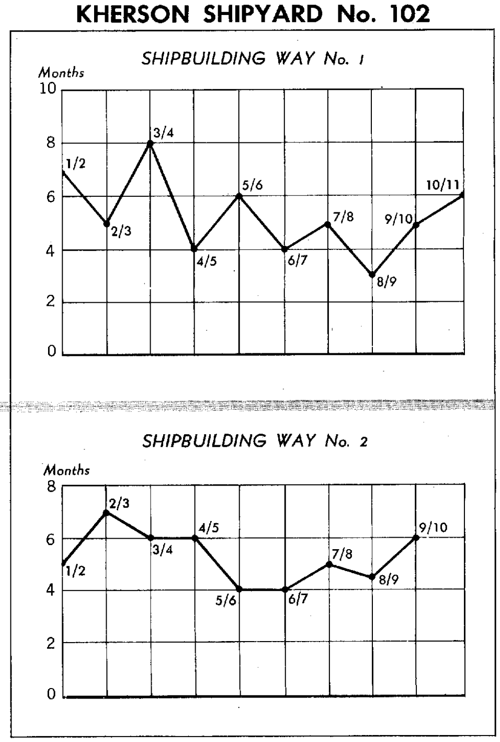

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Figure 4

USSR: ESTIMATED CONSTRUCTION SCHEDULE
KAZBEK-CLASS TANKERS
ADMIRALTY SHIPYARD No. 194, LENINGRAD

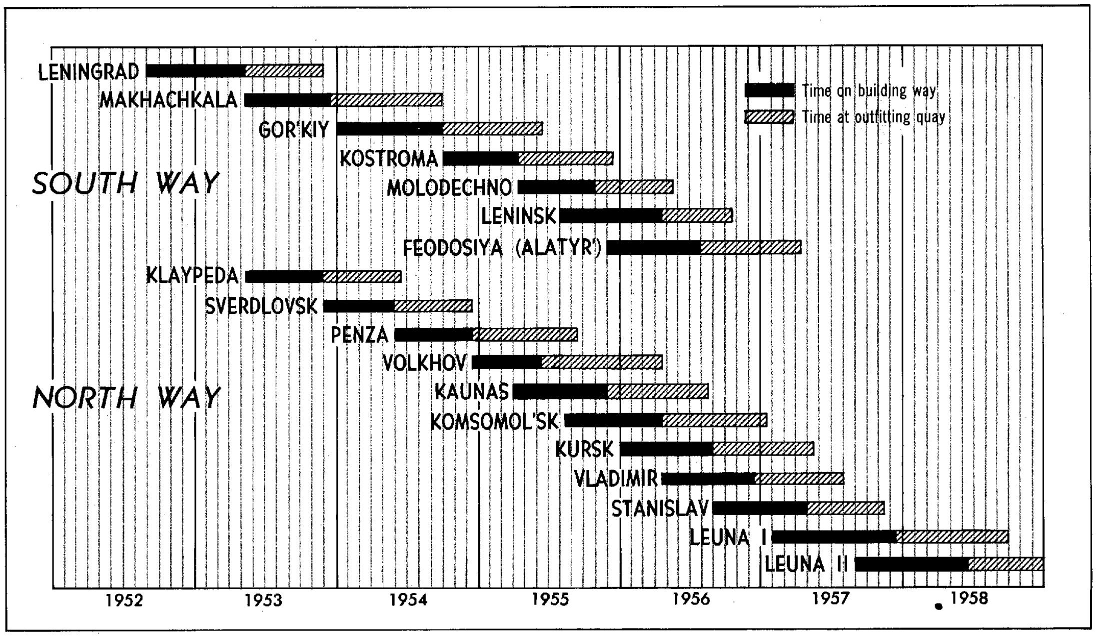
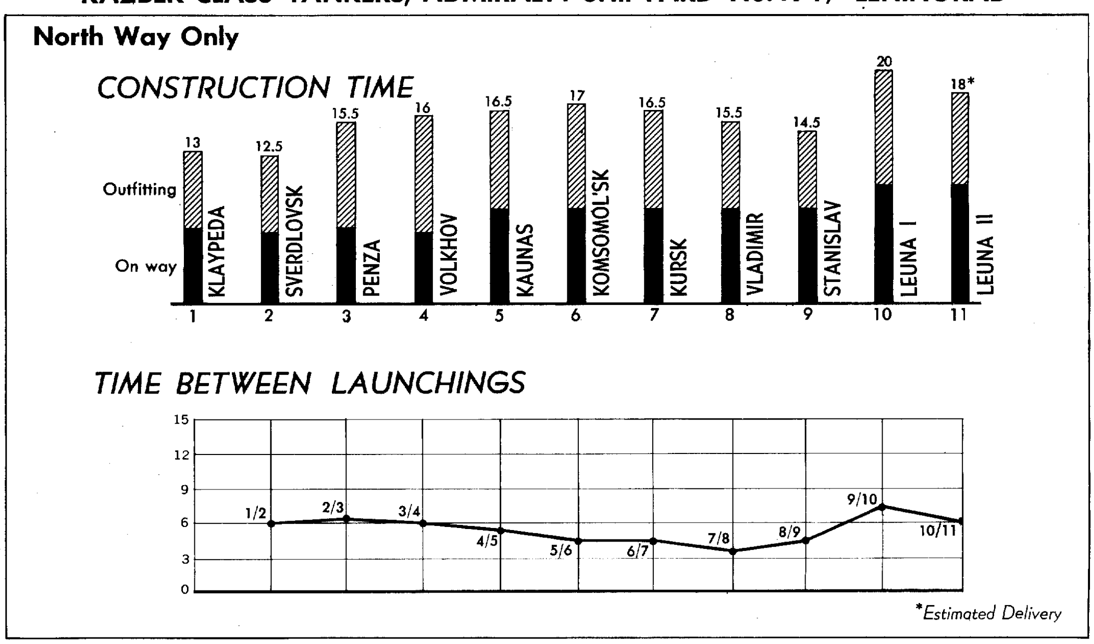


Figure 5

USSR: CONSTRUCTION TIME AND TIME BETWEEN LAUNCHINGS, IN MONTHS
KAZBEK-CLASS TANKERS, ADMIRALTY SHIPYARD No. 194, LENINGRAD



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It became apparent that this shipyard in late 1953 began construction on each way of one and a fraction tankers. This practice apparently was abandoned in late 1955. Possibly vessels of higher priority, such as the 3 whale catchers, were laid down on the same ways with the tankers and prohibited the continuation in 1955 of construction of one and a fraction tankers.

The estimated construction time is shown in Figure 7.* The average construction time was 15 months, but most vessels were produced in about 14 months. The time between launchings was reduced from about 7 months for construction of a single vessel to about 3-1/2 months for one and a fraction tanker giving an increase in tonnage constructed per way per year of about 50 percent.

On the basis of a launching every 3-1/2 months construction per month per shipbuilding way is estimated at nearly 1,200 metric tons. Average construction for all tankers was about 720 tons per month per way.

It is noted also in Figure 7* that with the beginning of construction of one and a fraction tankers there was a reduction in construction time. A similar reduction did not take place in the Admiralty Shipyard. In the Nosenko Shipyard apparently the shipyard labor force assigned to tanker construction was increased proportionately with the increase in number of vessels under construction. Also, the new cruiser way, on which these tankers were built, is served by 5 mobile tower cranes, whereas the north way in the Admiralty is served by only 4 mobile tower cranes.

III. Program for "Aktyubinsk"-Class Refrigerator Vessels

In 1955 the Baltic Shipyard in Leningrad began the serial construction of refrigerator vessels.

The basic characteristics of these vessels are as follows: length over-all, 429 feet; length between perpendiculers, 387 feet; breadth over-all, 55 feet; loaded draft, 25 feet; full load displacement, 10,250 metric tons; and estimated light ship weight of 4,150 metric tons. The volume of the refrigerated holds is 242,000 cubic feet, all of which can be cooled to 0° F. The propulsion plants consist of a single double-armature, direct-current, main drive motor, powered by 4 diesel-generators. These diesel-generators are ZD 100 mark diesels developing 1,800 hp each at 810 revolutions per minute (rpm) and model GP1-375-810 diesels developing 1,375 kilowatts (kw), 5,000 volts (v), each, at 810 rpm.

It is estimated that 14 refrigerator vessels will be completed and delivered by the end of the calendar year 1958. (Twelve were delivered by September, and two additional vessels are in the final stages of fitting out.) All estimates are based on these 14 vessels. Possibly 2 to 4 additional vessels are under construction.

These vessels have been constructed on three inclined shipbuilding ways. The method of construction used on two of the shipbuilding ways (east and west Ways) is similar to that employed by the Admiralty and Nosenko Shipyards in construction of the <u>Kazbek</u>-class tanker wherein one and a fraction vessels were constructed simultaneously on a shipbuilding way.

On the third shipbuilding way, the so-called battleship way, two full refrigerator vessels were constructed simultaneously. As a matter of interest, the first two vessels constructed on this way were laid down end to end, and small icebreaker tugs were constructed alongside each refrigerator vessel. The second group of two refrigerator vessels were laid down side by side at the foot of the way; the upper part of the way was occupied by partial construction of the large 27,000-ton cargo carrying capacity tanker.

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* Following p. 4, above.

Figure 8* shows the estimated schedule for construction and Figure 9* the time on ways and between launchings.

A comparison of total construction time for vessels constructed on the east and west shipbuilding ways shows that for the west way an average construction time of 20.7 months was required whereas for the east way an average time of 16 months was required. The average way time for the west way was slightly more than 13 months and for the east way slightly less than 10 months. Both ways are about the same size, and from reports both ways employed generally the same construction procedures. Crane facilities, however, are not equal. These two ways lie parallel to each other, and crane rails lie along the east side of the east way and between the east and west ways but not along the west side of the west way.

The east crane rails, on which are mounted three 12-ton tower cantilever cranes, serve only the east way; the crane rails between the east and west ways, on which are mounted two portal jib cranes (capacities unknown) and one 45-ton tower jib, serve both the east and west ways. Despite the availability of 3 cranes for each way (the heavy lift crane is located on the rails between the two ways and undoubtedly serves both ways) the east way has the distinct advantage of cranes on both sides of the way, and these cranes can be used jointly to move heavier sections, thereby reducing construction time. It is believed that this arrangement of cranes is the principal reason for the difference in construction time on the two ways. A comparison of tons per month per way shows that for the west way construction averaged 460 tons per month per way, and for the east way 620 tons per month per way.**

IV. Man-hours and Rates of Construction

Analysis of rates of delivery of tankers and refrigerator vessels show that Soviet claims for reduced construction time are not apparent in changes in rate of construction. It is believed that the scheduling of construction in a particular Soviet shipyard is affected by (1) the priority of the program itself (tankers or refrigerator vessels) and (2) priority of other construction in the shipyard (other vessels or subcontracts for other shipyards or industry in general). Because these priorities fluctuate over time, the rate of construction at a given time cannot be compared with the rate of construction at another time for the purpose of measuring technological advances in construction.

Soviet technical journals cite techniques employed in their shipyards which, from US experience, are known to reduce both cost and construction time. The two articles in Appendix A are good examples of improvements in Soviet techniques.

Soviet claims for reduced costs and man-hours are probably true. Reduction in construction time shows in Soviet records as a reduction in man-hour per vessel rather than a shorter construction period. It is true that in some instances certain vessels were constructed in shorter periods than others constructed before and after. Such cases, however, probably resulted from special effort or priority.

Little is known about the actual man-hours required to construct merchant vessels in the USSR. Several Soviet texts, however, throw some light on this subject. In Smirnov's "Approximate Methods for Determining Construction Costs of Maritime Ships" (Moscow 1956 pp. 1 to 70) man-days of direct labor is estimated for a series of dry-cargo vessels of cargo carrying capacity of 250 to 10,000-tons. For a cargo vessel of cargo capacity of 10,000-tons, serially constructed, construction of about 10.9 tons of light ship per man-year (direct labor) is indicated. (One man-year equals 307 eight-hour man-days.) On this basis about 1.1 million man-hours of direct shipyard labor are required to construct a Kazbek-class

* Following p. 6.

** Assuming a light ship weight of 4,150 tons and 85 percent of weight in place at time launching.

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Figure 6

USSR: ESTIMATED CONSTRUCTION SCHEDULE
KAZBEK-CLASS TANKERS
NOSENKO SHIPYARD No. 444, NIKOLAYEV

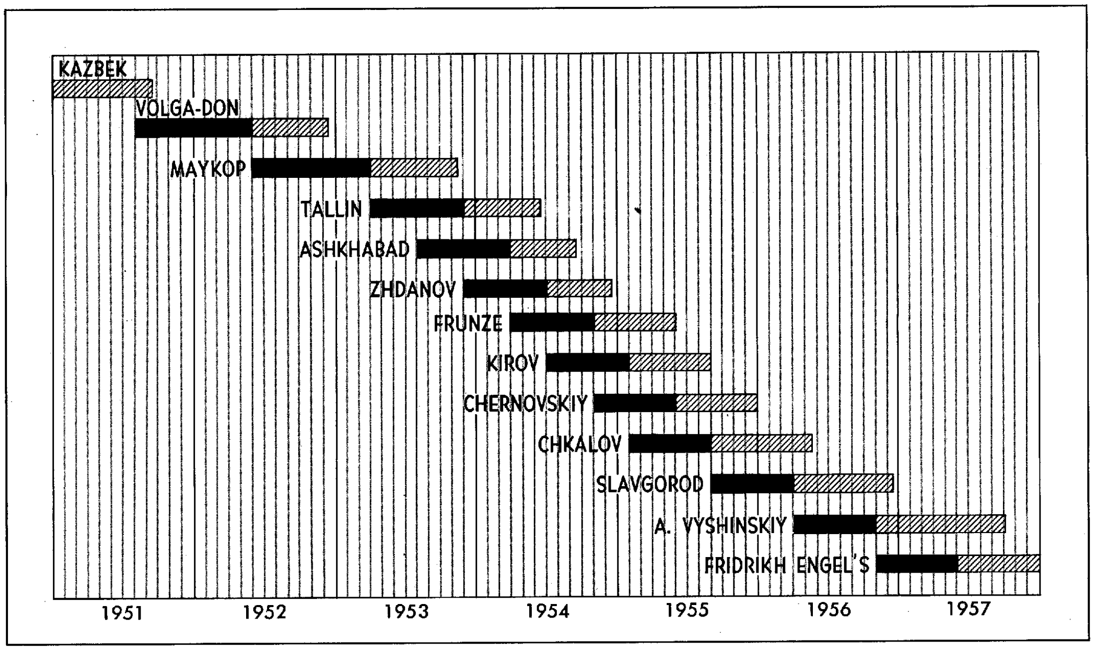

Figure 7

USSR: CONSTRUCTION TIME AND TIME BETWEEN LAUNCHINGS, IN MONTHS
KAZBEK-CLASS TANKERS, NOSENKO SHIPYARD No. 444, NIKOLAYEV

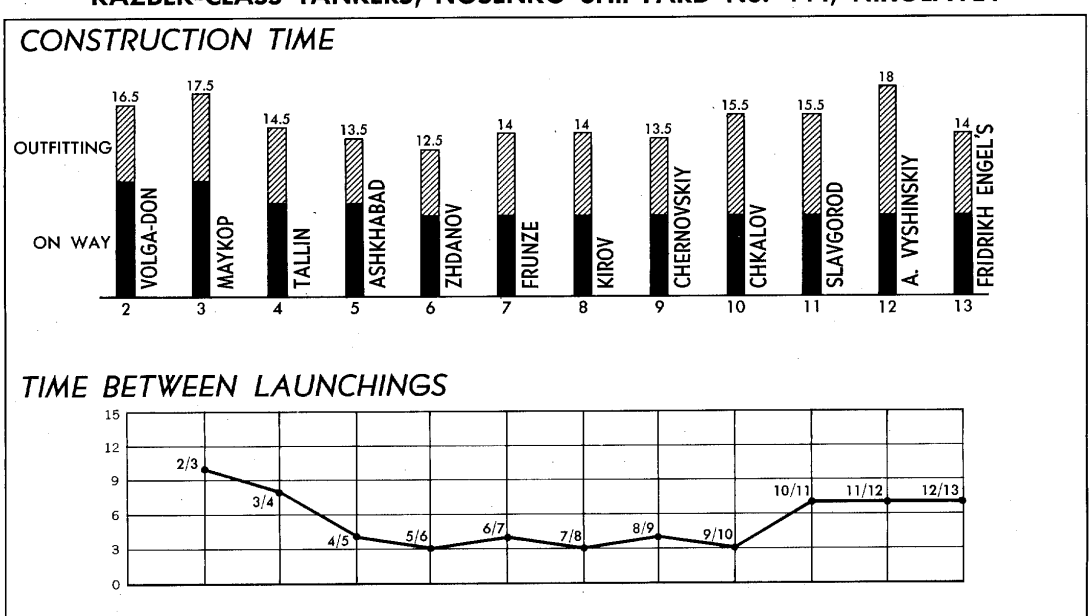

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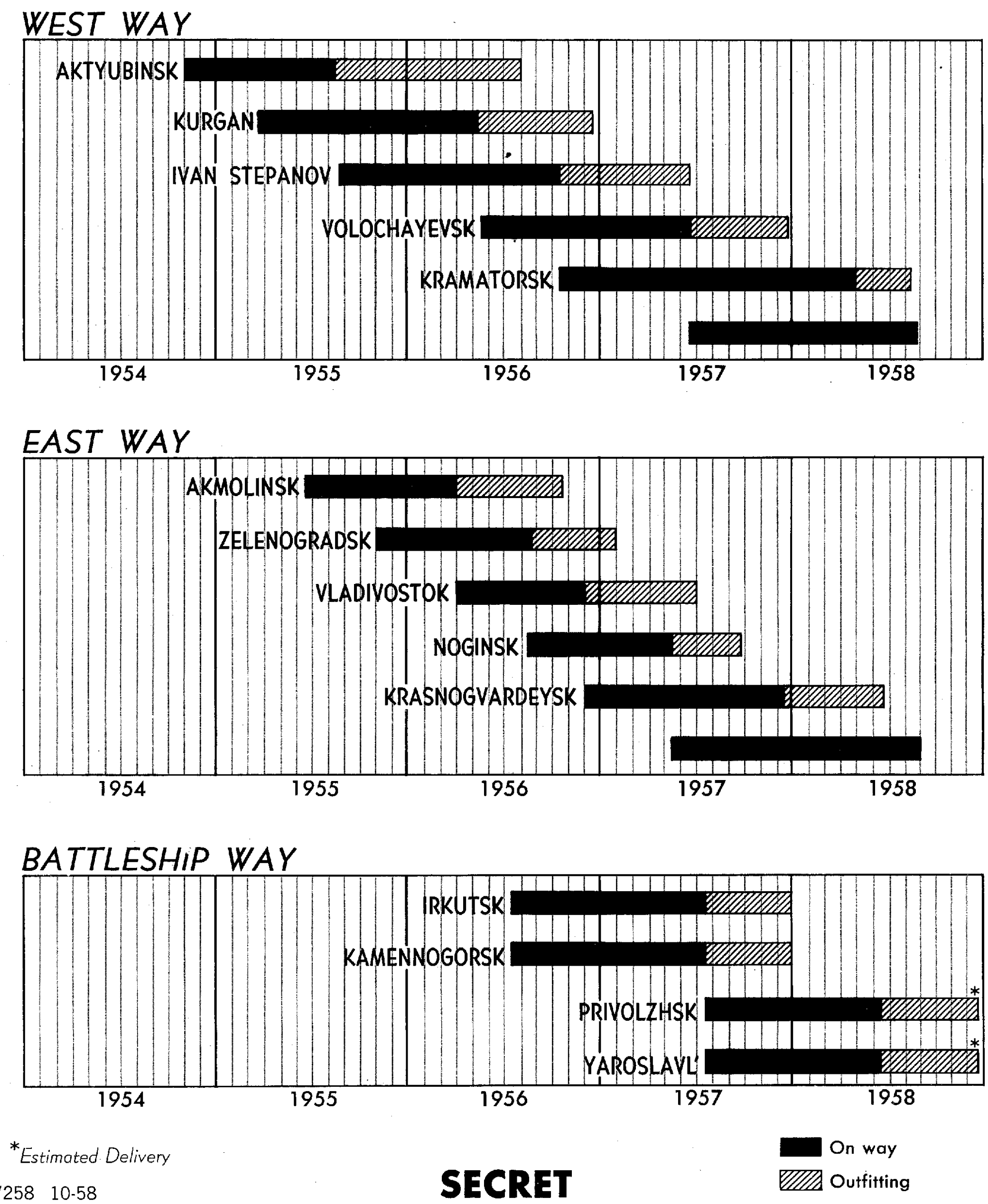
Figure 8

USSR
ESTIMATED CONSTRUCTION SCHEDULE AKTYUBINSK-CLASS REFRIGERATOR VESSELS
BALTIC SHIPYARD No. 189, LENINGRAD



*Estimated Delivery

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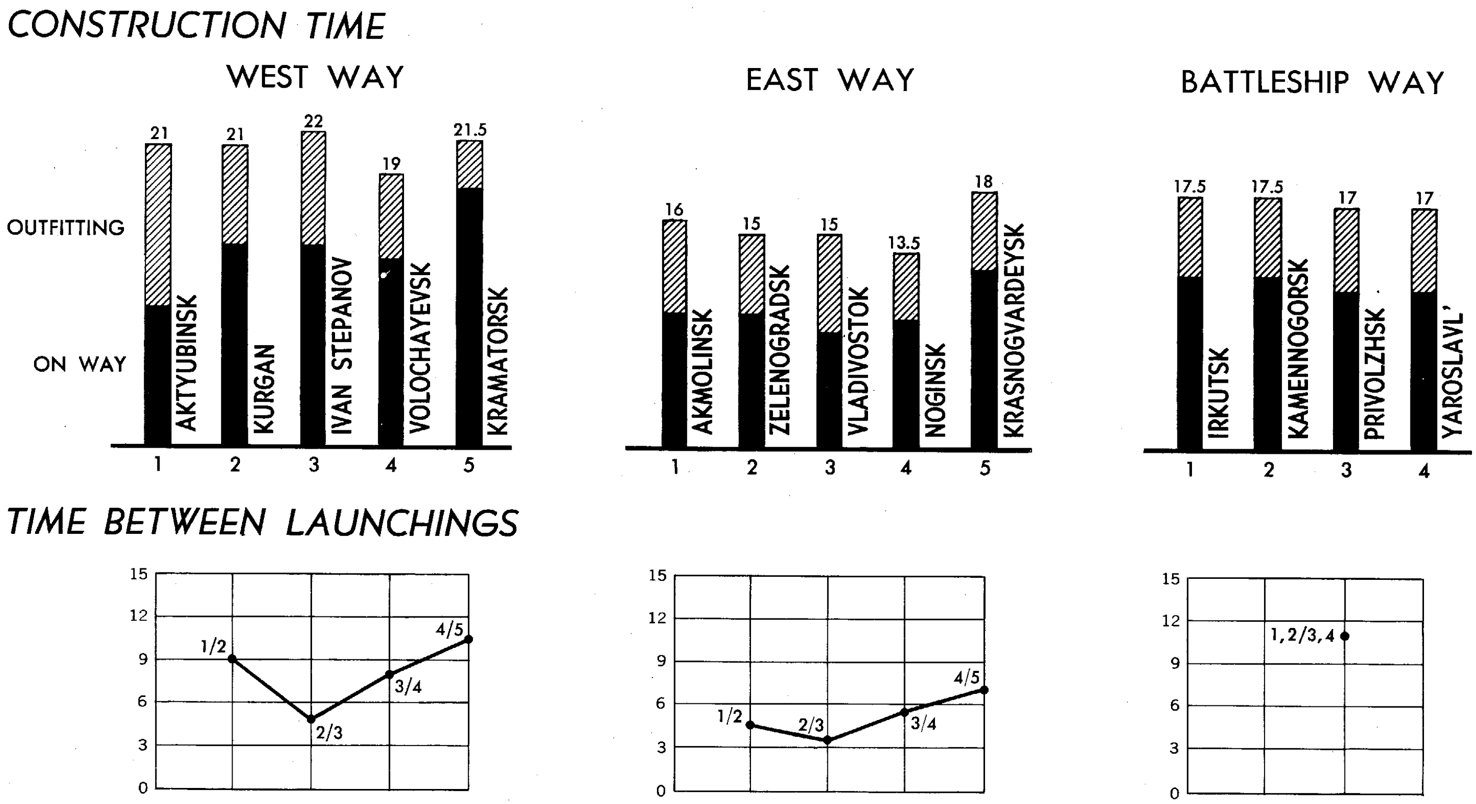
Figure 9

USSR: CONSTRUCTION TIME AND TIME BETWEEN LAUNCHINGS IN MONTHS, AKTYUBINSK-CLASS REFRIGERATOR VESSELS

BALTIC SHIPYARD No. 189, LENINGRAD



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tanker. This estimate compares favorably with Western practices and indicates that construction methods are similar, particularly in labor-saving techniques.

The figure following p. 18 of Appendix A is believed to reflect accurately comparative inputs of labor and costs for the first four refrigerator vessels. Similar claims have been made for other series-constructed vessels.

V. Conclusion

Soviet shipbuilders are acutely aware of the gains that are possible through the use of advanced techniques of welding and prefabrication. Considerable effort in this direction is apparent from articles in technical journals and reports of observers of Soviet shipbuilding practices. The time required to construct a Kazbek-class tanker or an Aktyubinsk-class refrigerator vessel, however, does not indicate a rapid rate of construction even in peacetime, compared with the construction rate of some of the better Western shipyards.

The man-hours required to produce similar vessels show that there is no material reduction in comparison with Western practice.

From this study and other reports on Soviet shipbuilding it is apparent that the shipbuilding industry is making considerable progress in modernizing its facilities and building techniques. Also, it is apparent that the Soviet leaders have developed this industry as a permanent sector of the Soviet economy and not as a temporary one merely to replace fleet losses in war.

APPENDIX A

This appendix contains partial translation of two articles describing tanker and refrigerator vessel construction. These articles appeared in issues of Sudostroyeniye (Shipbuilding), a Soviet monthly technical publication.

I. EXPERIENCE IN THE CONSTRUCTION OF TANKERS OF THE "LENINGRAD"* TYPE -- Leningrad, Sudostroyeniye, No. 5, August 1957.

Construction of Leningrad class tankers designed to haul petroleum products of various types between European and Asian ports began in 1953 in one of the (Leningrad) shipbuilding plants.'

The tanker's main specifications are: length over-all 145.5 meters, breadth 19.2 meters, depth 10.4 meters, cargo dead weight 10,000 tons, displacement 16,250 tons, speed in trials 13.3 knots, and operating range 10,000 miles. The ship has quarters for 44 crew members and 12 trainees, housed mainly in single-place cabins.

The hull is divided by 16 transverse and two longitudinal bulkheads into 33 main water-tight compartments (not counting double bottom compartments), including 24 cargo tanks and two cofferdams. The pumping room is amidships and the engine room is aft.

The tanker's power plant consists of two USSR-built, two-stroke, solid injection, single-acting model 8DR 43/61 engines of 2,000 horsepower at 250 revolutions per minute. Both of the left-turning engines operate on one propeller shaft, through hydraulic couplings and reduction gears.

The ship's auxiliary engines are two 2-stroke, solid-injection model 4D 30/50 engines of 400 horsepower at 300 revolutions per minute. Two model KVS-68/1 auxiliary boilers with a heating surface of 200 square meters, 15 atmospheres pressure, and steam capacity of 10 tons each per hour are provided for steam engines which operate cargo pumps and for heating of cargo.

The tanker's fire-prevention safeguards include carbon dioxide, foam, steam, and water extinguisher systems. The ship has four chambers with a 4M-2FV-8/4 refrigeration plant to store perishable products.

The cargo system is served by four steam, reciprocating, direct-acting PNP-250 pumps of 250 cubic meters' capacity each per hour, under a 100-meter water head pressure. Cargo piping is arranged on the ring system.

The hull consists of 340 sections comprising 11 technological compartments. The welding sequence for compartments corresponds to the numbering of the compartments, i. e., 1, 2, 3, etc. The hull is built on the ways by the compartment method, with sections of compartment I welded first, then of compartment II, which is welded to compartment I, and so forth. (See Figure 1 ** for numbering of compartments in the lead ship.)

The first tanker was to have been built in 14 months, according to the plan, during which time preparations for series production of the ship had to be completed. The plant created specialized shops to meet the pecularities of building tankers, and created specialized brigades

* Also referred to in Soviet technical articles as Kazbek-class.
** Following p. 10.

for this purpose. The production procedures adopted made it possible to complete in the plant's shop about 52 percent of the total volume of work to build the tanker, including fabrication of superstructure blocks. The volume of building way work amounts to about 34 percent of the total volume. The tabulation below shows the percentage distribution of work.

Basic Types	Total	Including Superstructure Blocks	On Ways	After Launching	Total
Hull	23.94	3.79	14.75	0.75	39.44
Erection	4.90	1.27	11.90	8.20	25.00
Fitting Out	15.11	6.48	5.10	4.75	24.96
Machine Shop	6.00	--	--	--	6.0
Other	1.30	0.30	1.80	1.50	4.60
Total	51.25	11.84	33.55	15.20	100.00

Introduction of assembly line method for hull steel machining made it possible to reduce labor input for this work by 12 percent pet tanker, and increase the yield per square meter of production area in hull machining shops to 16 percent over that in 1952.

Use of a photo-optical method for laying out components and scale marking methods reduced the total labor input in mold loft layout work 25.5 percent, increased the quality of the layout, and released 2,000 square meters of mold loft area for other production purposes.

Cold bending of hull steel, instead of hot, manual bending, raised labor productivity in bending work by 60-75 percent.

The original breadkown of the hull into sections was changed and the size of sections was increased to utilize machinery better and reduce work done on the building ways. As a result, the number of sections was reduced from 340 to 229, and the number of volume sections rose from 9 to 20. In the main, the hull's stern sections were enlarged. (See Figure 2* for the revised numbering of sections and assembly order.)

Labor input for assembly and checking of sections on the ways was reduced 15-18 percent by introducing a new technology of fabricating sections in the shop, with the surplus edges already trimmed to the established tolerances, which shortened assembly and welding time on the ways.

A pyramidal scheme for assembly and welding on the ways was introduced to replace the original compartmental method. Transfer to this method was one of the important factors which made it possible to reduce work time on the building ways from 8 months on the first ship assembled by the compartmental method, to 3 months and 8 days on the tanker Vladimir.

Water testing of compartments was replaced with compressed air testing, which simplified the testing process and reduced the cost.

* Following p. 10.

Construction of tankers at two positions on the building ways was worked out and accomplished for the first time in shipbuilding, to utilize the area of the building ways to the maximum and reduce building time. (See Figures 3 and 4* showing sequence of assembly at two positions and the bow of a nearly completed tanker and the stern section of another on the ways.)

This method consists of building at the head portion of the ways a stern compartment weighing more than 1,000 tons and equal to one third the length of a tanker, at the same time that a complete tanker is being built in the lower portion of the ways. The tanker's stern compartment, with its engine room, is the portion of the ship with the most machinery and systems and amounts to about 30 percent of the total work per ship.

Completion of work on the stern compartment should coincide with or slightly precede completion of work on the ship built in the lower portion of the ways. After launching of the first ship, the stern compartment is lowered slightly to the second position with a special device. In the second position, middle and bow portions are completed at the same time that the stern section of the next ship is laid out in the first position. This technology reduced tanker building ways time 1.5-2 months.

Of the total of 9,160 pipes installed on the tanker, a large portion is 50 millimeters in diameter or larger, as is shown in the tabulation below.

	Number of Pipes		
Diameter of Pipes	Steel	Copper	Total
Up to 32 mm	1,255	1,832	3,087
32-50 mm	1,610	306	1,916
Over 50 mm	3,895	262	4,157
Total	6,760	2,400	9,160
Fabrication of Pipes (larger than 50 mm in diameter)			
Documentation of the designer			
By Drawings	1,684	18	1,702
By Templets at site	2,221	244	2,455
Actually Used at plant			
By Drawings	2,184	18	2,202
By Templets at site	1,711	244	1,955
Pipes Requiring Bending			
Cold			
On Machines	3,338	487	3,825
Manually	1,255	1,832	3,087
Hot	676	47	523

* Following p. 10.

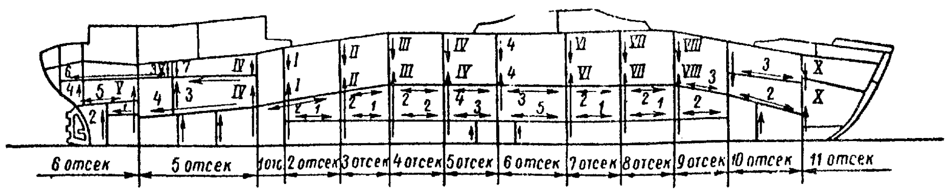

Figure 1. Numbering of Compartments [OTCEK or OMCEK] and Assembly Sequence.

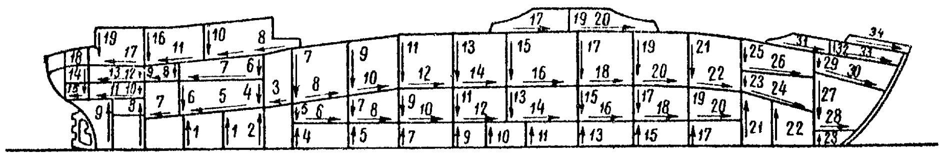

Figure 2. Numbering of Sections for Sectional Assembly.

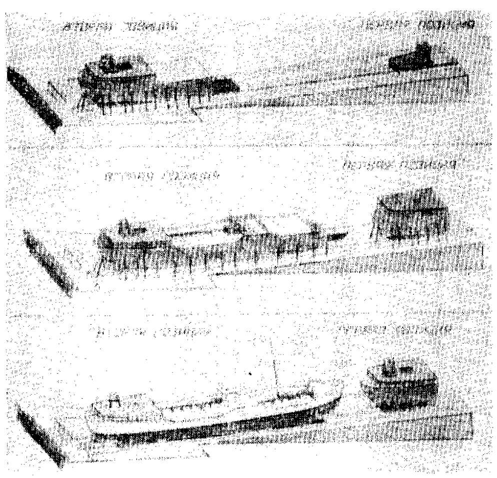

Figure 3. Diagram of Two Position Tanker Construction Method. First Position at Right and Second Position at Left.

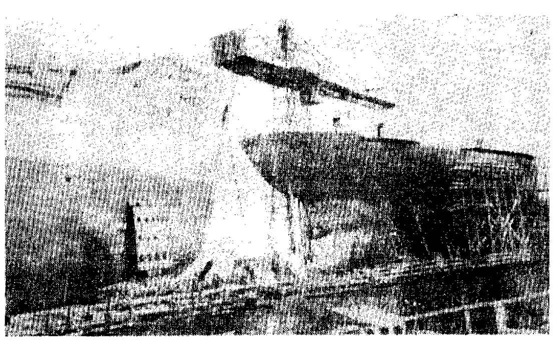

Figure 4. Simultaneous Assembling of 2 Tankers On One Building Way. Complete Tanker Assembly Left. Stern Compartment Assembly On Head of Ways at Right.

The original technical documentation called for complete fabrication in the shop of only 1,702 pipes and all the rest to be fabricated at the site. However, several steps taken increased the number of pipes fabricated completely in the shop by drawings to 2,202 pipes. A total of 3,825 pipes are bent cold with engine-powered and manually powered pipe-bending machines.

The paint shop has painted more than 62,000 square meters of surface on various components with sprayers in the last 5 months, and labor productivity per worker here has reached 50 square meters per hour.

Wooden flooring for interior decks has been replaced with mastic, giving a saving of 65,000 rubles per tanker.

After the tanker is launched, the superstructure, weighing about 170 tons, is installed on the ship with the help of a floating crane. The block method of fabricating superstructures reduces the tanker building time by 2-2.5 months through simultaneous work on the superstructure and hull.

More than 300 changes have been made in parts for the tanker since 1953, to improve technical and operating characteristics.

Plant workers have published ten brochures and more than 20 articles explaining the achievements of advanced workers in production and their experiences in building Leningrad class tankers at this plant. This was of definite help to other plants building tankers of this class.

A total of 763 suggestions resulting in an annual saving of 326,322 rubles have been introduced in 4 years of building tankers.

In 1956 the plant, in close collaboration with scientists, completed work on designing, fabricating, and testing of corrugated bulkheads which made it possible to make strong, simple and lighter bulkheads. Tests showed that corrugated bulkheads (photograph in article) weigh about 20 percent less, and manufacturing labor input is also about 20 percent less than the usual flat bulkheads. The materials from work completed were turned over to the TsKB (Central Design Bureau) for planning new large tankers.

Work done to prepare for production, to introduce advanced technology, to improve design, and to generalize and disseminate advanced experience, and other measures made it possible for the plant to reduce the labor input for building tankers by approximately 800,000 man-hours, to reduce the building cost of tankers in 3 years by more than 40 percent, and to increase labor productivity 45 percent.

II. ORGANIZATION OF SERIES CONSTRUCTION OF REFRIGERATOR SHIPS AT BALTIC PLANT -- Leningrad, Sudostroyeniye, No. 5, May 1957

The Northern Shipbuilding Yard in Leningrad began construction of seagoing refrigerator ships of the Kooperatsiya and Dzerzhinskiy class in 1927. The Soviet Union's maritime fleet was augmented by several new ships of this class during the preway 5-year plans. The better refrigerator ships of prewar construction include the steamers Dnepr and Kooperatsiya, the motor vessels Volga, Neva, and Kuban', and ships of the Smol'nyy and Dzerzhinskiy class.

A series of seagoing refrigerator diesel-electric ships, whose plan was developed on assignment of the Ministry of Fishing Industry USSR, is now being built at the Baltic Plant (Baltic Shipbuilding Plant imeni S. Ordzhonikidze, Leningrad). Ships of this class are intended for hauling frozen and lightly salted fish from shore refrigerator plants or floating herring bases. The lead ship of this series is the Aktyubinsk.

Basic characteristics of the diesel-electric ships are: length over-all, 130.86 meters; breadth over-all, 16.8 meters; depth at the middle frame, 9.5 meters; loaded draft, 7.5 meters; displacement, 10,250 tons; dead weight when hauling frozen fish, 3,700 tons; dead weight when hauling lightly salted fish, 4,400 tons; dead weight when hauling fishing season cargo, 6,100 tons; volume of refrigerated holds, 6,850 cubic meters; operating region, unlimited; power plant type, diesel-electric, direct current, with four diesel-generators of 1,800 horsepower each; speed at full ahead, 16 knots; speed at full ahead according to trials data, 18 knots; cooling capacity, 300,000 large calories per hour; hold refrigerator remperature, 18 degrees centigrade.

Ships of the three-island type have found wide application in USSR shipbuilding, as contrasted with foreign practice where instead of the midships superstructure and forecastle, are mounted deck houses. A superstructure permits, with full framing of the ship, reducing free-board, according to existing Register USSR rules, and thus increasing the allowable drafts and cargo dead weight.

An engine room location in the after end and a two-island type with forecastle, elongated poop, and house amidships were adopted for this ship. The house amidships permits having a through passage along the upper deck from forecastle to poop, making it convenient for loading-unloading operations and for mooring.

All service and living quarters are concentrated in the midships and stern superstructures, and have square portholes to improve cabin illumination. The diesel-electric plant is located on a platform under the stern superstructure.

The ship's coefficient of cargo dead weight varies, according to the type of cargo hauled, from 33 to 47 percent.

The refrigeration plant is of the ammonia type, and consists of three two-compressor assemblies of the MKhM ADS-150 type with a cooling capacity 150,000 large calories per hour each. One assembly is for reserve.

Four model 3D-100 engines, two-stroke, 10-cylinder, with opposed pistons, and 1,800 horsepower at 810 rpm each, were adopted as main diesel-generators.

Voltage for the main propulsion plant current circuits is 1,000 volts, and 220 volts for the exciting and control circuits. Four direct-current main generators, model GP1375-810 of 1,375 kilowatts' capacity at 810 rpm and 500 volts, were designed and made by the (Leningrad) Elektrosila Plant.

Aspeed of 17.8 knots (in ballast)is attained with simultaneous operation of all four diesel-generators, 16 knots with three operating and 14.3 knots with two operating.

Installed as a driving motor is a double-armature, direct-current electric motor, model 2MP-7,000-115, of 2 x 3,500 horsepower capacity at 1,000 volts in the armature winding and a speed of 115-140 rpm, made by the Elektrosila Plant.

Engine operation is controlled in the engine room and from a central control station.

The direct-current diesel-electric plant permits using full diesel-generator power at various speed ranges and ensures better maneuverability than ships equipped with the usual diesel plants. Auxiliary diesel-generators are three DG-300 motors with four-stroke 8423/30 diesels of 450 horsepower at 750 rpm.

Auxiliary machinery, serving the main and auxiliary diesel-generators, the driving electric motor and the ship systems, is located in special spaces under the main diesel-generators compartment.

The Baltic Plant has come a long way in organizational and technical development during its 100-year existence. Organization of production which meets the present level of science and technical development, created at the plant in the postwar period, has made it possible to build large ships in large sections with application of manual and automatic welding on a wide scale, and also to introduce new technology in assembly, installation and fitting-out work.

Many new types of machinery have now been installed and mastered in the plant, and the newest methods and work procedures have been introduced. The amount of equipment, devices, and special tools used has more than tripled.

In wide use are automatic welding and cutting, new installations with high-frequency currents, ultrasonics, radioactive elements for quality control, and also photo-optics and other achievments of modern engineering. The system used to organize preparation for production has been simplified and improved. All of this has made it possible for the plant to carry on continuous construction of ships.

The technology and organization of building refrigerator ships provides full utilization of the plant's production capacities.

The technology for building the refrigerators is as follows: the ship is divided into ten volume compartments; assembly joints of side and bottom sections are combined to permit dividing the ship hull into volume compartments as these joints; the superstructures are built by the block method (blocks of the superstructures are made in tiers, the volume and weight of which correspond to the building ways' crane equipment); and the ship is built according to steps and through technological complexes.

The ship's hull is completely formed on the building way, and is provided with maximum erection of machinery and equipment, including all decks of the superstructures, masts, pipes, and gear. (Figure 1* shows how the ship is divided.)

The stern, as the part of the ship equipped with the most machinery, is formed in the first step. Construction proceeds according to standard technological documents.

The basic proposals summarized, adopted in technological development of the ship design, have fully justified themselves in practice and ensure meeting plan technical-economic indexes and also obtaining some above-plan profit.

A. Division of Ships Into Sections, Regions, and Construction Stages.

The ship hull is assembled on the building ways from volume and flat sections, made in the assembly-welding shop, with full equipment installation and the application of automatic welding for as much as 75 percent of the total welding volume.

Volume and flat sections are made in the shop on beds with removable, curved beams; work also is done in the shop to clean, prime, and test welded seams and fit out sections with machinery components and foundations.

* Following p. 19.

The ship's hull is divided into six construction regions (engine-boiler room, holds, and superstructures), and consists of 250 sections, a considerable portion of which weigh 40-60 tons, as shown in the following tabulation.

Name of Section	Number of Construction Region 1	2	3	4	5	6	Total Sections
Bottom	3	--	2	3	2	--	10
Side	6	35	8	8	12	24	93
Transverse bulkheads	4	--	4	4	1	--	13
Longitudinal bulkheads	--	1	--	--	2	--	3
Lower deck	4	--	10	8	4	--	26
Upper deck	--	18	3	3	5	6	35
Recesses	7	36	--	--	5	21	69
Structures forming blocks	--	--	--	--	--	--	--
Smokestacks, companion hoods	--	2	--	--	--	--	2
Total Sections in region	24	92	27	26	31	51	251
Weight of sections	305.9	315.0	378.7	441.7	326.0	103.4	1,868.7
Weight of facing components	6.0	--	7.0	8.0	3.0	--	24.0
Total weight (Tons)	311.9	315.0	385.3	449.7	329.0	103.4	1,892.7

The ship's entire construction period was divided into 14 technological stages: three prebuilding way, six building way, three fitting out, and two delivery stages.

All construction work was computed according to special planning-accounting units -- through technological complexes -- which describe construction finished, accomplished in the required technological sequence. The ship's hull is formed on the building site in 6 months (six technological stages).

Methods adopted in building the ship ensure a broad front of erection work, completed in parallel with the hull work. About 60 percent of the total volume of erection and machine building work is complete at launching, and about 70-75 percent of the total volume of work is complete at launching.

B. Problems of Ship Construction Technology

New technological processes were used in building refrigerator ships which helped to increase the volume of mechanized production processes and raise lablor productivity. Chief of these are the following:

1. Machining hull metal in a closed production cycle, which reduced considerably the production time and cost per ton of metal machined.

2. The photo-optical method of marking hull structure components, and automatic cutting by copy-drawings on a MDFKS machine (Scale, Remote, Photo Copying System).

3. Cold bending of hull components and straightening them under hydraulic presses and powerful rollers.

4. Shot-blasting and chemical cleaning of scale from hull components.

5. Assembly of large sections with assembly joints which ensure normal conditions for their transport and reduction of the erecting-fitting manual labor on the building site.

6. Welding of flats without cutting, and fitting sheet edges in a flux cushion with increased tolerances, on a magnetic stand.

7. Testing of compartments with air pressure instead of hydraulically, which cuts the length of testing time in half and permits wintertime testing.

8. Gas planning instead of manual, pneumatic chipping.

9. Application of a method of equal distribution of loadings on bearings of suspended traction dynamometers in erection and centering of drive shafts.

10. Cold bending of pipes on machines, using high-frequency current heating, and automatic butt welding of the brine-carrying pipe bank.

11. Insulation of holds with mineral felt and mineral cork instead of expensive "ekspanzit" (presumably an expanding insulating material), and application in production of clays in a bituminous base.

Improved building technology and a higher level of labor mechanization have required a larger amount of rigging. About 1,000 descriptions of special rigging, which include beds, stands, jigs, installations, conductor jigs, stamps, special tools, gauges, etc., were developed.

The most characteristic types of rigging include dismountable curved beds, the electromagnetic stand, stamps and jigs for cold bending of hull components, jig machines SM-150 for contact-butt welding of pipe coils and oxygenous scavenging of burrs, a device for mechanical beading of copper piping, use of the POV-1 instrument to measure and control propellers and cones, shot-blasting installations and etching baths, universal machine clamps, and several other types of equipment.

Mechanized hand electric tools used include mortising machines, drills, planes, joiners, saws, shears, etc., a total of more than 520 special electric tools. More than 600 special pneumatic tools have been used, including nut wrenches, caulking hammers, angular and other types of boring machines, pain sprayers, etc.

An average of one million rubles was spent on equipment and special tools for each refrigerator delivered by the plant in 1956; the cost of the ordinary tools for one refrigerator ship is 200,000 rubles.

C. Peculiarities of Technology of Erection and Fitting-Out Work.

The propulsion plant of the refrigerator ship has about 60 descriptions of various electric machinery and ship gear; the ship has, in addition, 33 different pipes and systems.

The over-all length of piping for sewage drains for various working quarters -- water, steam, brine, ammonia, and air -- is about 45 kilometers, and this amount weighs about 200 tons.

Machinery-erection work on refrigerator ships is done by two main shops -- the coppersmith and machine-erecting shops. About 90 percent of all pipes machined in the coppersmith shop are bent by the cold method on machines. A specially mastered shop device (photograph in source) handles the bending of thick-wall steel pipes with high-frequency currents. All operations in the shop for preparing pipes have been mechanized -- bending, turning of flanges and collars, cutting of holes and pipe testing.

In building refrigerator ships, the ship hull is equipped to the maximum with mechanical equipment. A considerable volume of all erection work is done during the building way period, and manual work in fabricating and erecting of pipes, systems, and machinery has been mechanized.

Use of special, portable cutting and boring machines for machining rectangular and round foundations has reduced the time needed for machining foundations to one fifth or one sixth the former time, and has reduced the labor input to less than one third the former amount.

New modern equipment and progressive technology have made it possible to perform basic ship erection work during the building way period of forming the ship hull. Installation of main and auxiliary machinery and a considerable portion of the piping and systems is completed during this time. The plant has the task in the future of completely finishing all installation work during the building way period, except for some deck machinery to be erected afloat.

All of the refrigerator ship's electric equipment can be divided into two basic groups: (1) electric equipment of the propulsion plant; and (2) electric equipment of auxiliary machinery.

Erection of all electric equipment and cable in the refrigerators is handled by the electric-erection shop of the plant. Electric-erection technology was improved in the following chief ways: (1) mechanization of labor-consuming fitting and preparatory work done in subshops; (2) further standardization of fastenings for cable and electric equipment, and use of more modern design fastenings in production; (3) transfer of the maximum possible volume of electric erection work to the subshops.

The following are new technological processes, means of mechanization, and other measures to improve electric erection work:

In performing shop fitting-preparation work, fabrication of cable fastenings has been transferred almost completely to stamping, and various bending work is done on improved bending machines. Cable terminal boxes designed by the plant itself are being used to fasten cable on all ships built at the plant. Separation of cables has been transferred mainly from the ship to the shop, which has reduced the labor input in this operation 25-30 percent.

A new method of separating high-voltage cables, by using polyvinyl chloride insulation bands instead of the rubberized band and specially strong fibers formerly used, has been introduced.

In assembly of low-voltage current apparatus, a method of pressing stamped blocks of terminals cold onto strands of cables of 1-1.5 square milimeters cross-section, instead of soldering points and separating cable strands "on a ring" in the light fixture, has been introduced.

Expensive brass strips and marking scales have been replaced by laminated plastics.

Fitting out work amounts to about 30 percent of the total volume of work in building a ship. The heterogeneous nature and the large nomenclature of work in furnishing and finishing quarters requires exceptionally clean organization of production, and mechanization of manual work.

Workers of various specialties take part in furnishing and finishing of quarters: fitters-out, carpenters, painters, joiners, insulators, electricians, pipefitters, and others. Therefore, it is especially important to observe strict technological sequence in performing this work.

Advance preparation for production of refrigerator ships was made, considering the peculiarities of fitting-out work in furnishing quarters. Combined plans for installing preinsulation components which permitted doing this work in one fitting-out shop by specialized brigades, were made at the suggestion of the plant TsKB (Central Design Bureau).

Such organization of work in furnishing of quarters increases labor productivity, reduces the amount of work on the ship to be redone, and makes it possible to install insulation and equipment fastenings in a shorter period of the building way assembly of the hull. This in turn makes it possible to work on a broad front on the building way, considerably reducing fitting-out time afloat for the ship.

Widely used are stamped components of a fitting-out nomenclature, and contact spot and seam welding of thin-sheet parts instead of manual electric arc welding.

A large number of wooden parts go aboard a refrigerator ship: a total of about 2,500 cubic meters of wood and more than 600 tons of insulating materials are used. Holds and interior and exterior decks are covered with wood, and all interior intercabin bulkheads, hot hatch covers, trim for parade spaces, and furniture are made of wood. The plant woodworking shop does all this work.

Special attention has been given to mechanization and to improving technology and organization of the woodworking shop in connection with the expansion of this type of work. Additional drying kilns have been installed to meet completely the demand for dry wood. Steps are being taken to increase capacity of the preparatory and joining sections of the woodworking shop by mechanizing loading-unloading and transport work within the shop, to increase the machine park, and to modernize machines now in use. Work is being done to equip the paint spraying chambers, to permit mechanization of manual labor in lacquering furniture and trim parts for quarters. Labor-consuming manual work in caulking grooves and planing wooden flooring of decks has been completely mechanized.

D. Organization of Ship Trials.

Testing and delivery of the ship to the orderer is provided in two consecutive technological construction stages: (1) mooring tests afloat at the plant wall; and (2) state acceptance running trials at sea.

On the lead ship (the diesel-electric refrigerator Aktyubinsk), all problems related to trials and delivery of the ship, main and auxiliary machinery, equipment, gear, systems, and piping were worked out. The brine system of the ammonia refrigerator plant was subjected to especially extensive reworking, which considerably extended the acceptance trial period for this refrigeration plant. Much reworking also was done in the steam heating systems and others.

The organization and techniques for conducting trials in series refrigerators were revised. Clean working programs for testing the most important units were worked out; for example, making the program more precise permitted reducing the electric driving engine's testing cycle at moorings from 80 to only 31 hours.

Much work was done to train and select personnel for the delivery crew and testing group. A uniform schedule for running trials, which provided a maximum combining of individual test stages and rational sequence for them, was worked out. Refrigeration plant trials were combined with running trials.

These steps gave a considerable reduction in the length of tests, as seen from comparison of data on test length for the lead refrigerator Aktyubinsk (April-July 1956) and the last ship delivered in 1956, the Zelenogradsk (November-December 1956), given in the following table:

	On Series Ship	On Lead Ship
Mooring tests	32 days	76 days
Running tests	5 days	6 days
Inspection and control withdrawal	10 days	18 days
Total	47 days	100 days

The total trials time was reduced to less than half.

E. Analysis of Labor Input and Construction Cost.

The labor input in a series refrigerator ship was computed on the basis of the technology developed, taking into account mastery of construction, introduction of organizational-technical measures, new equipment, and rationalizing proposals received from advanced production workers during the construction period.

Mastery of construction and introduction of progressive technology ensured a systematic reduction of labor input on each consecutive ship. Labor outlays, based on an index of 100 for the lead refrigerator Aktyubinsk, were as follows for successive series ships: 80.5 for the Akmolinsk, 71.8 for the Kurgan, and 70.7 for the Zelenogradsk. (Figure 2* shows a graphic comparison of labor input and costs for these ships.)

The reduction of labor input ensures a sharp reduction in construction cost. The cost of series ships is 71 percent of the lead ship cost.

Many changes were made in the design of many components of the hull, gear, equipment of systems, and machinery during the process of building and testing the first four refrigerator diesel-electrics. Substantial corrections were made in the originally planned technological processes, especially the erection work.

This work was done by a collective of workers, foremen, technologists, and plant builders in cooperation with the plant design bureaus, the design bureaus of contracting plants, scientific research institutes of the Ministry of Shipbuilding Industry, the Leningrad Refrigeration Institute, and other organizations.

Much help was given the plant by a group of supervisors from the orderer, the Vostokrybkholodflot Trust (Far Eastern Fishing Refrigerator Fleet Trust?); a group of supervisors from the Register; crews of the diesel-electrics Aktyubinsk, Akmolinsk, Kurgan, and Zelenogradsk; and the lead ship acceptance commission under the chairmanship of I. M. Semenov, Deputy Minister of Fishing Industry USSR.

* Following p. 19.

F. Changes Made in the Design of the Lead and Subsequent Ships Included:

1. Ship hull changes -- the design of the stem and adjacent parts was simplified; intermediate platforms in the hold were eliminated; the design of the joint for the bilge stringer was changed; and external bridges on the bow and stern superstructures were eliminated.

2. Insulation and quarters trim changes -- the change to insulating holds and 'tweendecks with mineral felt and mineral cork instead of expensive "ekspanzit"; the change in design of lathing and lacing for hold insulation, 'tweendecks and service and living quarters insulation; revisions in the design of many items of quarters equipment, including furniture, to reduce labor input in their fabrication and increase operating qualities.

3. Systems and piping changes -- the change in the layout of the brine carrying system to permit improved operation of the plant in refrigerating holds, and to introduce a three-stage cooling system; introduction of settlers in the draining system and thermostats for the steam heating system, designed by the plant; improved strainer design for the piping of the main and auxiliary diesel-generators' cooling system; and a radical change in design for the steam separator of the exhaust boilers, hot well, etc.

4. Electric and mechanical parts changes -- the introduction of standardized terminal boxes designed by the plant for fastening electric cable, instead of the fastenings provided by design, which were unsatisfactory in manufacture and operation; changing the alternating current schemes, simpler erection and operation, etc.

Considerably improved were the technological processes for hull work, assembly of diesel generators, driving motor, shaft line, piping, systems, insulation, erection, and other jobs, and also the installation of cargo, boat, and anchor gear.

Series production of ships permits correct distribution and utilization of available production capacity and ensures equal loading of sections and organization of continuous production.

Outlays for manufacture of rigging and specialized tools are rapidly being recouped, and introduction of the latest achievements in equipment and technology is ensured. -- D. N. Balayev (Director, Baltic Shipbuilding Plant imeni S. Ordzhonikidze, Leningrad)

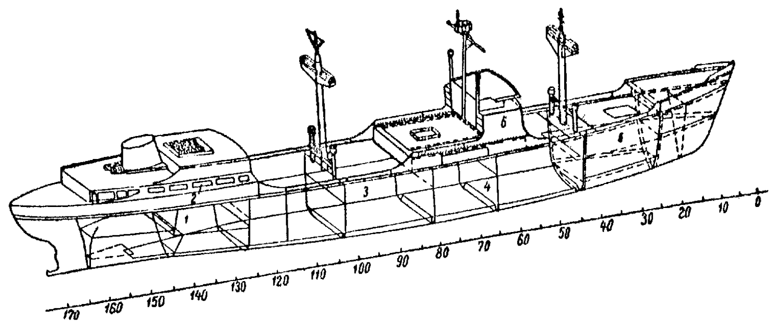

Figure 1. Division of the Ship Into Building Way Construction Positions (numbers designate ordinal numbers of building way positions.

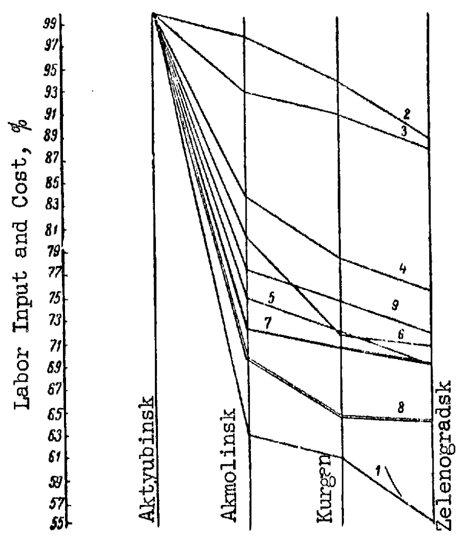

Figure 2. Comparison of Labor Input and Construction Cost of the lead and series refrigerator diesel-electric ships: (1) labor input for machining hull steel; (2) labor input for assembly and welding of sections; (3) labor input of building way assembly; (4) labor input of erection work; (5) labor input of fitting-out work; (6) actual labor input of all work; (7) planned cost; (8) actual cost; (9) norm of labor input.